Geosynthetics, J. Kuwano & J. Koseki (eds)

Strength-deformation characteristics of lightweight geomaterial mixed with EPS beads

Minegishi, K. & Makiuchi, K.
Department of Transportation Engineering and Socio-Technology, College of Science and Technology, Nihon University, Japan

Keywords: geofoam, EPS beads, lightweight geomaterial, strength deformation characteristics, traffic loads

ABSTRACT: This paper describes mechanical characteristics of a lightweight geomaterial mixed with EPS (Expanded Poly-styrol) beads. EPS beads are added to Kanto loam (one of volcanic cohesive soils in Japan) which is presumed as a construction generated surplus soil and the method of construction to build embankment using cement-stabilized lightweight geomaterial is widely used recently in Japan. EPS is a super-lightweight artificial material which belongs to a geofoam in geosynthetics, and an EPS bead has a soft and elastic nature. The lightweight geomaterial mixed with EPS beads used in this study contains EPS beads by 1.7% and cement stabilizer by 7% in dry mass ratio with Kanto loam. The laboratory testings which are carried out in this study are unconfined compression test, triaxial compression test, cyclic triaxial compression test and consolidation test. The strength and deformational characteristics of lightweight geomaterial mixed with EPS beads under the static and cyclic loadings are discussed.

1 INTRODUCTION

Because Japan is confined in an area, embankments by lightweight banking methods are often constructed on a poor ground and a steep slope spot recently. Manifold researches concerning lightweight geomaterials that blend a weight saving material with a natural soil are carried on presently as one of its countermeasures. This technology can reduce earth pressure acting to a retaining wall and is possible to prevent a differential ground settlement.

Prompt exploitation of the lightweight geomaterials is well received since an effective reuse of construction generated surplus soil causing resent social troubles in this country is able to be promoted.

The laboratory testings such as unconfined compression test, triaxial compression test, cyclic triaxial compression test and consolidation test were carried out in this study to investigate mechanical properties of cement-stabilized lightweight geomaterial mixed with EPS (Expanded Polystyrene) beads.

Table 1. Physical property of soil (base material).

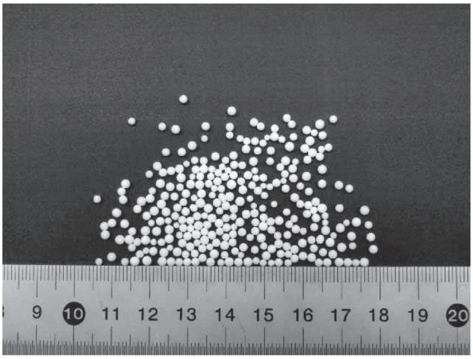
geomaterial name	kanto loam
soil particle density ρ_s(g/cm^3)	2.72
liquid limit w_L (%)	143.4
plasticity index Ip	42.5

2 LIGHTWEIGHT GEOMATERIAL MIXED WITH EPS BEADS

2.1 *Materials used in the experimental works*

The soil (basic) material used in the test is a volcanic cohesive a soil (Kanto loam taken in Funabashi City Chiba Prefecture in Japan) which is often abandoned as a construction generated surplus soil. In the beginning the material was cured at a state of air-dry condition in laboratory. The physical property of soil is shown in the Table 1. EPS beads (density ρ_B = 0.033 g/cm^3, average grain diameter D = 1.8 mm) shown in Photo 1 are used as the weight saving material.

The procedure to make test specimens is described below. Firstly, a portland cement stabilizer (a specified agent for cohesive soils) by 7% in dry mass ratio with a basic material is blended with a air-dried Kanto loam (w ≒ 90%), and it is mixed well. Next, EPS beads by 1.7% in dry mass ratio (34.4% in a volume ratio) with basic material are mixed and it is mixed again with adding water so that its moisture content becomes 120%.



Photograph 1. EPS beads.

2.2 *Specimens*

The cylindrical specimens of an unconfined compression test, static triaxial compression test and a cyclic triaxial compression test are made at a diameter of 5 cm and in a height of 10 cm by the use of a vinyl chloride mold, the lightweight geomaterial which was determined as the wet density becomes ρ_t = 1.1 g/cm^3 was compacted using a 2.5 kg-rammer in around 5 times per layer in 3 layers. The specimens excluding a weight saving material are compacted to become in ρ_t = 1.4 g/cm^3. The consolidation specimens in a disk shape are made in a diameter of 6 cm and in a thickness of 2 cm using a cutter ring after the lightweight geomaterial which was decided as the wet density becomes in ρ_t = 1.1 g/cm^3 was compacted using a 2.5 kg-rammer in around 25 times per layer in 3 layers. The specimens without EPS beads are made with Kanto loam and the cement stabilizer material by the same method mentioned above. The specimens of the compression tests and the consolidation test are maintained using the polyethylene film under airtight condition for seven days. The tests were performed after that curing.

3 EXPERIMENTAL METHODS

3.1 *Static mechanical testings (JGS 1990)*

A static unconfined compression test and a static triaxial compression test (UU-test) are carried out based on JIS A 1216 and JGS 0521, respectively. A consolidation (compression) test is performed based on the JIS A 1217.

3.2 *Cyclic triaxial compression test on the assumption of traffic loads*

A cyclic triaxial compression test is carried out to investigate strength and deformational characteristics of the lightweight geomaterial which is used for the embankment materials of a road and a railroad.

The dynamic stress ratio (σ_d/σ_s) is defined as the ratio of repetitive axial stress σ_d to the static strength σ_s which is obtained from results of static triaxial compression tests. Cyclic triaxial compression test is performed by using the dynamic stress ratio (σ_d/σ_s). The cyclic test conditions are shown in Table 2. The testing was terminated at that moment when it collapsed (ε_t > 15%) before reaching the designated load repetition numbers.

Table 2. Loading conditions of cyclic triaxial compression test.

Numbers of loadings, N	15000, 100000
loading wave type	sine wave
control method	stress control
confining pressure, σ_3 (kPa)	20, 40, 60, 80, 100
dynamic stress ratio	0.2, 0.4, 0.6, 0.7, 0.8
frequency (Hz)	1, 5

4 RESULTS OF EXPERIMENTAL WORKS

4.1 *Static unconfined compression test and triaxial compression test*

Figure 1 illustrates the results of unconfined compression test and triaxial compression test. It is shown in unconfined compression test results that the unconfined strength attains to destruction after the increase concerning linear stress-strain relation was shown and definite peak stress was appeared. On the other hand, it is seen from results of triaxial compression test that influence of confining pressure is remarkable, and it is understood that maximum principal stress differences (σ_1-σ_3 max) increase with increase in the confining pressure. The result shows a slow increase tendency gradually though an increase tendency concerning linear stress-strain relations is shown right after text starts, until it reaches test end, and no distortion occur except in the case of confining pressure σ_3 = 20 kPa.

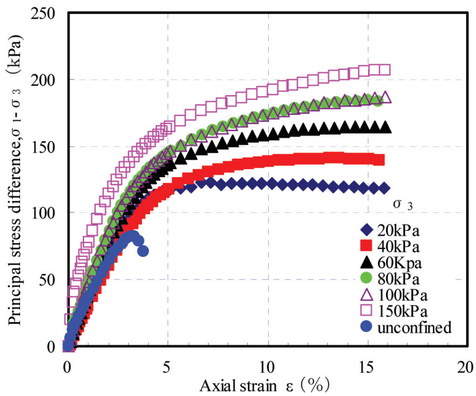


Figure 1. Principal stress difference-strain curves (Static triaxial compression test and unconfined compression test).

Figure 2 shows relationships between maximum principal stress difference and confining pressure based on the above results of static triaxial compression test. The relations can be expressed in the next equation (1).

$$\sigma_1 - \sigma_3 = -0.0061\ \sigma_3^2 + 1.73\ \sigma_3 + 85.4 \qquad (1)$$

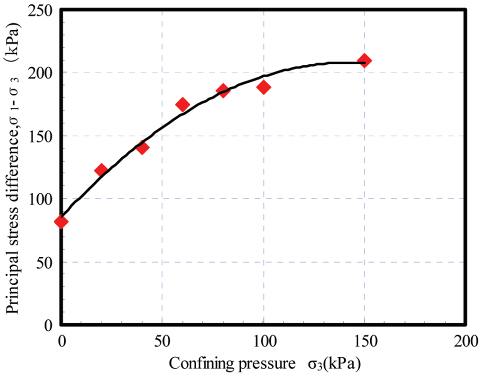


Figure 2. Reationship between maximum principal stress difference and confining pressure.

4.2 *Cyclic triaxial compression test*

4.2.1 *Relations between total axial strain and numbers of cyclic loadings*

Figure 3 shows relations between total axial strain and loading numbers of stress repetitions in the case of confining pressure $\sigma_3 = 20$ kPa and a rate of loading 1Hz. Total axial strain is the distortion which is the amount of deformation under loading divided by the initial height of specimen. The result shows a tendency that the total axial strain increase, as numbers of loadings increases. However, no remarkable distortion can be found up to 15000 loadings at a low dynamic stress ratio of 0.2~0.4 within this test range and the total axial grow to about 1~2%. Though they do not reach destruction, it is may be readily understood that an excessive large total axial strain is caused in a dynamic stress ratio of 0.6~0.7. In the case of dynamic stress ratio of 0.8, it reaches failure at loading numbers of approximately 1000. The variation of plastic axial strain (axial strain which is an irrecoverable axial strain under unloading) shows the same tendency to that of total axial strain although it is not illustrated here.

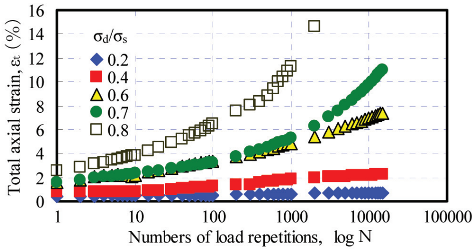


Figure 3. Effects of dynamic stress ratio on total axial strain.

4.2.2 *Relationships between elastic axial strain and numbers of cyclic loadings*

Figure 4 shows the variation of an elastic axial strain in the same test condition as Figure 3. The elastic strain is the value of a recoverable axial strain which is given as the difference in axial strain loading and in unloading. The elastic strain indicates a resilient property of specimen when unloading. The elastics strains maintain almost constant value until test end and little influence of ratio of dynamic stress can be found. Total axial strain accumulates as numbers of loadings progresses. On the other hand, the elastic axial strain almost shows a constant value. Therefore, it is inferred that axial strain is restored in the part of elastic EPS beads in the process of unloading.

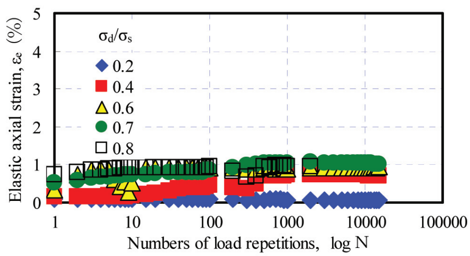


Figure 4. Effects of dynamic stress ratio on elastic axial strain (confining pressure 20 kPa, 1 Hz).

4.2.3 *Influence of loading frequency*

Figure 5 shows the influence of loading frequency on relationships between total axial strain and numbers of loadings. There is a little increase in the total axial strain, and only a few percentage of the strain at 100000 loading repetitions. Consequently, it is understood that the influence of dynamic stress ratio isn't exerted and same tendency can be seen at the range of low dynamic stress ratio and high frequency.

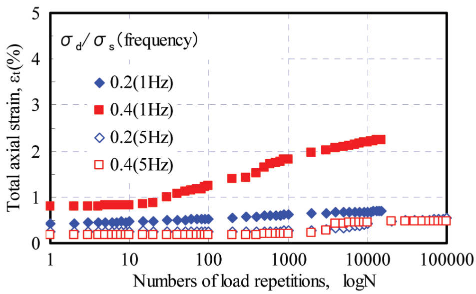


Figure 5. Effects of frequency on total axial strain (confining pressure 20 kPa).

4.3 *Consolidation test*

4.3.1 *Consolidation yield stress*

Generally the consolidation yield stress *pc* for natural geomaterials is determined using *e* (void ratio)-*log p* curve. However, deformation of EPS beads own is remarkably large. Therefore, in this study, *Vr-log p* curves are used as a substitute for *e-log p* curves. The compressive strain *Vr* is expressed in the equation (2).

$$Vr = \Delta H/H_0 \qquad (2)$$

H_0: initial height of specimen,
ΔH: specimen's height under each consolidation pressure.

Figure 6 illustrates *Vr-log p* curves. Table 3 shows consolidation yield stress p_c of each specimen determined from the *Vr-log p* curves.

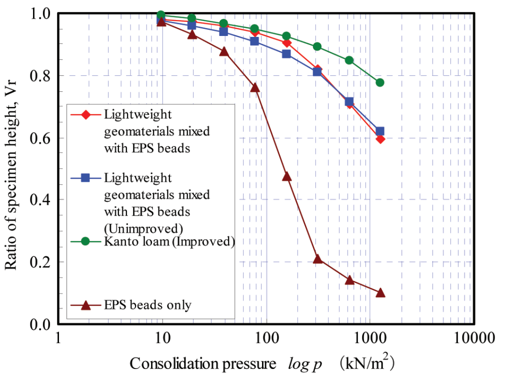


Figure 6. Effects of consolidation pressure on compressive strain.

Table 3. Consolidation yield stress, p_c.

Specimen	p_c (kN/m^2)
Lightweight geomaterial mixed with EPS bead	290
Lightweight geomaterial mixed with EPS beads (Unimproved)	170
Kanto loam (Improved)	620
EPS beads only	100

4.3.2 *Effects of EPS beads on the deformational characteristics of specimens*

It is shown is Figure 6 that the compressive deformation or consolidation of both the improved and unimproved lightweight geomaterials mixed with EPS beads are smaller than that of the specimen of EPS beads only. In addition the compressive deformation of lightweight geomaterials mixed with EPS beads increase remarkably with the increase in consolidation pressure in the range beyond their own consolidation yield stresses, in the similar manner of the specimen of EPS beads only.

It can be inferred from the results that the consolidation yield stress p_c is regarded equivalent for the pore (air) pressure in the internal parts of EPS beads distributed in the lightweight geomaterial.

4.3.3 *Effects of cement stabilizer on the strength of specimens*

As shown in Figure 6, there is no remarkable difference in the *Vr -log p* curves between the improved specimen and the unimproved specimen. The consolidation yield stress is 170 kN/m^2 for the unimproved lightweight geomaterial mixed with EPS beads. On the other hand, it becomes 290 kN/m^2 for the cement-improved lightweight geomaterial mixed with EPS beads. Therefore, it can be understood that the compressive strength of specimen increases by adding a cement stabilizer to the lightweight geomaterial mixed with EPS beads.

5 CONCLUSIVE REMARKS

Conclusions obtained from the tests in this study are summarized as follows:

(1) Both total axial strain and plastic axial strain increase with the increase in numbers of loadings or in dynamic stress ratio.
(2) Elastic axial strain is not affected seriously by numbers of repetitive loadings.
(3) The total axial strain decrease with the increase in loading frequency.
(4) Consolidation deformation of lightweight geomaterial mixed with EPS beads is not affected by a cement stabilizer.

REFERENCES

Ed. by The Japan Geotechnical Society (JGS) (1990). "Geotechnical Testing Methods", pp. 289-315 and pp. 339-348.